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THE IMPACT OF EXCESS MOISTURE IN THE BALE ON FIBER QUALITY

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Abstract

The impact of spraying moisture on cotton fiber at the lint slide, packaging the bales at universal density, and storing the bales for 149 days at atmospheric conditions was evaluated in this study. About 40, 38, 28, 19, 12, and 0 (control) pounds of water were sprayed on fiber at the lint slide to six bales of cotton before storage. Initial lint moistures prior to moisture addition were about 4.8%. Moisture contents after the over spray was applied were 12.7, 10.4, 12.0, 8.5, 4.8 and 7.4%. After the bale storage phase was completed, the final moisture contents were 8.2, 7.0, 7.6, 6.4, 6.1, and 6.6%. The bale without any over spray increased from 4.8 to 6.1% moisture content during storage and the bale with 12 pounds of water added changed its moisture content from 7.4 to 6.6%. All bales that had moisture added lost weight during storage. The initial HVI color was 31 for all bales except the control bale that was color 32. After storage, the bales initially above 8.5% moisture were graded Middling Light Spot (32) as compared to 31 before storage. Caution should be exercised when applying moisture to cotton before long term storage and bales should be stored at below 8% moisture content, wet basis, regardless of bale covering materials.

Introduction

Cotton fiber and cottonseed continually seek to reach equilibrium with the moisture in the air. Uncompressed cotton fiber gives up moisture readily at low humidity but absorbs moisture much more slowly at high humidity. After cotton fiber is baled, moisture transfer occurs very slowly especially at high densities. In fact, bales at densities of 12 lb/ft^3 required over 60 days to equilibrate with the environment while bales at 28 lb/ft^3 required over 110 days (Anthony, 1982), obviously, equilibration time is a function of the starting moisture as well as the humidity and temperature of the environment. The bales attempt to reach equilibrium with the environment and the rate of adsorption and desorption is influenced by bale density, ambient temperature and humidity, bale covering, surface area, air changes, fiber history, etc. (Anthony, 1997). Anthony (1982) stored low-moisture bales for periods up to one year and found that moisture gain was a function of density, climatic conditions and bale covering. He considered jute, burlap, woven polypropylene, strip-laminated polypropylene, dimpled polyethylene and polyethylene. Bales covered in the relatively impermeable polyethylene required much more time (over 365 days) to equilibrate with the environment than the other bale coverings (over 120 days).

Ginners often restore moisture at the lint slide to reduce bale-packaging forces and to recover the weight lost during field drying and gin processing (Anthony, Van Doorn and Herber, 1994). Two basic methods are used—humidified air and direct water spray. The humidified air approach rarely adds more than 2% moisture to a bale but the direct spray approach can add far more. Thus, the direct spray approach must be used with great care. Griffin and Harrell (1957) investigated the effect of adding moisture at the lint slide on lint quality and bale weight for 18 bales packaged at 12 lb/ft^3, covered with jute bagging and stored for 70 days. They considered different amounts of moisture sprayed on the fiber with and without a surfactant with nine nozzles as the lint came down the lint slide. The amounts ranged from 0 to 82 pounds per bale in 1953-54. They conducted a similar study with six bales in 1954-55 except that the bales were packaged at standard density (about 20 lb/ft^3) and 0 to 35.7 pounds of water was added per bale. In 1953-54, bale moistures ranged from 3.9% to 18.8% whereas they ranged from 4.6% to 9.0% in 1954-55. They found that all the bales either gained or lost weight as they tried to reach equilibrium with the atmosphere at about 7% moisture content. Of the 18 bales in their 1953-54 study, no damage could be attributed to the addition of moisture at the lint slide except for the bales packaged at over 15% moisture; these bales developed mildew and fungal growth and were not graded. No damage to fiber quality or spinning properties was evident in bales packaged below 9% moisture. For the 1954-55 study, the color grade was reduced from Strict Low Middling to Low Middling when moisture was added at the lint slide to raise the moisture content even at storage moistures of 6.2%—this happened regardless of the amount added. They also reported that the center of the bales had not equilibrated with the atmosphere after 91 days. Anthony (1982) found similar results from 100 samples taken throughout bales stored for several months.

Current bale covering materials include burlap, woven polypropylene with laminated strips of polyethylene to prevent fibrillation, and polyethylene with 3/8" diameter perforations on 18" centers to allow moisture transfer. Anthony and Herber (1991) studied the moisture transfer characteristics of these materials applied over universal density bales that were packaged at 3.5% moisture and stored at 70 ºF and 80% relative humidity. They reported that the woven polypropylene-covered bales reached equilibrium in less than 161 days whereas the polyethylene-covered bales had not reached equilibrium after 378 days. After 161 days, the polyethylene-covered bales had gained about 40% as much moisture as the polypropylene-covered bales. With the exception of the Griffin and Harrell report, published information addresses moisture entering rather than leaving the bale. Barker and Laird (1993) reported that desorption occurs at about twice the rate of adsorption for small samples of lint. Thus, bales should lose moisture much faster than they gain moisture.

Rapid measurement of the moisture in cotton bales is very difficult, and becomes even more complex when water is sprayed directly to the cotton at the lint slide. Anthony (2001) reported success with hydraulic methods whereas Byler, Anthony and Galyon (2001) reported acceptable levels of accuracy using patented resistance-based sensors (Byler and Anthony, 1996). Until suitable methods to measure the moisture of baled cotton are readily available, care must be exercised to ensure that excessive moisture is not added to bales. Based on the work of Griffin and Harrell (1957), bales should not be covered with jute bagging and stored above 9% moisture content. Anthony (2002) evaluated the impact of spraying moisture on cotton fiber as it came down the lint slide, packaging the bales at universal density, and storing the bales for 116 days. Initial moisture contents after the water was added and before storage ranged from 6% to 15.4%. After 116 days of storage the bale in which no over spray had been applied had increased to 6.1% moisture content, all the other bale moistures had changed substantially even though the bales were triple-sealed in polyethylene bags. Most fiber quality characteristics except color remained about the same. The HVI color decreased from Middling (31) to Strict Low Middling Spotted (43) as final bale moisture content increased from 6.1% to 12.9%.

The addition of moisture to cotton fiber immediately before baling reduces compression forces, increases bale weight and reduces equilibration time. Generally, less than two percentage points of moisture (10 pounds) of moisture can be added to a bale of cotton by the humidified air approach. The direct-spray method can add a much greater amount of water but is generally limited to keep final bale moisture to less than 8%. Typically, less than 15 pounds of water is added, but unlike the humidified air approach, more moisture can be added. As mentioned earlier, too much water can be added and fiber damage and color changes from 31 to 43 can also occur.

The purpose of this work was to determine if moisture sprayed on fiber at the lint slide could adversely impact fiber quality.

Methodology

Six bales of Stoneville 747 variety cotton were processed through a cylinder cleaner, stick machine, cylinder cleaner, extractor feeder/gin stand, and one saw-type lint cleaner in a gin. As the lint came down the lint slide in 1- to 2-inch thick layers, three conventional spray nozzles applied water to the surface of the cotton. For bale number 5, no moisture over spray was used. For bales 1, 2, 3, 4 and 6, the nozzle tips were 0.003, 0.002, 0.003, 0.001 and 0.001 inches, respectively, orifice diameter. The parallel nozzles were positioned 18 inches above the cotton and sprayed in a flat pattern perpendicular to the cotton and achieved full coverage of the width of the batt. The three nozzles were connected to municipal water supply, and flow was regulated with valves. Total nozzle output at various valve settings was calibrated by capturing the water from the nozzles for a period of time. Water quantities were about 40, 24, 50, 16, 0 and 12 pounds, respectively for treatments 1-6, per 500-pound equivalent bale of cotton. Ten samples were taken as the cotton came up the lint flue to the battery condenser for High Volume Instrument (HVI), Advanced Fiber Information System (AFIS), and moisture evaluation. After moisture was added, 10 samples were taken for lint moisture evaluation. The bales were pressed to a platen separation of about 19-inches. The bales were restrained with 9-gauge, 89-inch long wire ties and placed in industry-approved, strip-laminated, woven polypropylene bags and then weighed. The bales were then stored (Figure 1) for a period of 149 days in a gin building. As shown in Figure 1, the tops of the bags were not folded and fastened as is normal practice but were left open. This procedure may have hastened moisture transfer. The bales were ginned November 16, 2001, and were taken out of storage on April 16, 2002. The bales were subjected to conditions inside the building, which were generally 60 to 80°F with humidity fluctuating proportionate to climatic conditions outside. Temperature and relative humidity were not recorded.

After the 149-day storage period, 10 intermediate locations (layers) were identified on each bale beginning 3 inches from the side of the bale and marked (Figure 2) before the bale ties were removed so that samples could be taken at specific locations. Subsamples were taken at each layer for moisture content (10), AFIS (10), HVI classification (6) and biological degradation (10). The cotton was separated at each layer and samples taken as shown in Figure 3. The 100+ gram samples taken for biological degradation were shipped directly to the Cotton Quality Research Station at Clemson, South Carolina. During transit, these samples were stored in doubled Ziploc® polyethylene bags and their conditions were maintained essentially at atmospheric. The classification samples were stored in paper bags while awaiting classification. The Agricultural Marketing Service, Dumas, AR, and Memphis, TN, classed the samples. Moisture and AFIS analyses were conducted at the Stoneville Ginning Lab.

Results

Based on calculations from the moisture levels as determined by the oven, 40.4, 28.2, 37.7, 18.8, 0, and 12.4 pounds of water were added to bales 1-6, respectively (Table 1). Lint moisture contents in the lint flue prior to moisture being added were 4.9, 4.7, 4.7, 4.7, 4.9, and 4.8%, respectively, for bales 1-6. The moisture contents after the over spray was applied were 12.7, 10.4, 12.0, 8.5, 4.8 and 7.4 %, respectively for bales 1-6. After the bale storage was completed (149 days), the final moisture contents were 8.2, 7.0, 7.6, 6.4, 6.1, and 6.6%. The distribution of moisture at each layer is illustrated in Figures 4 and 5 for the low and high moisture bales, respectively. No visible water damage was observed except near the bale ties (Figure 6). The weight change in pounds per bale is shown in Figure 7. The 4.8% moisture bale gained weight but all the others lost weight. Moisture change is estimated for each bale in Figure 8. Only one bale, the low-moisture one, gained moisture during storage. The bale without any over spray increased from 4.8 to 6.1% moisture content during storage. The bale with limited amount of water added changed its moisture content from 7.4 to 6.6%. The bale with 18.8 pounds of water added, changed its moisture content from 8.5 to 6.6%. All bales that had moisture added lost weight during storage. Note that the bales were stored at atmospheric conditions from November 16, 2001 to April 16, 2002.

The AFIS data for the cotton before and after storage is in Tables 2 and 3, respectively. Differences do exist in some data but the samples should likely be re-run as one group in a completely randomized fashion in order to eliminate potential problems with machine differences.

The Classing Office at Dumas, AR, evaluated the "before storage" HVI samples and the Classing Office in Memphis, TN, evaluated the "after" HVI samples because the Dumas systems were under renovation. Unfortunately, there seemed to be a threshold shift in some of the quality factors. These data showed all initial color grades as 41 and all final color grades as 32. The "before and after" samples collected for AFIS analyses were retained after AFIS analysis and used as classification samples at the same time by the Dumas Classing Office in August 2002, and these new data was used in subsequent analysis.

Sample classification by the Agricultural Marketing Service for the bales before storage is presented in Table 4. The mode HVI color was 31, 31, 31, 31, 32, and 31 for bales 1, 2, 3, 4, 5 and 6, respectively. Five of the samples for bale 5 were 32 and four were 31, so the color was called 32. Rd averaged 74.7, 74.2, 74.6, 74.3, 73.3 and 73.6, while Plusb averaged 9.2, 9.0, 8.9, 9.0, 9.2 and 9.1, respectively for bales 1, 2, 3, 4, 5 and 6.

The HVI data after storage is shown in Table 5. After storage, the bales initially above 8.5% moisture were graded Middling Light Spot (32) as compared to 31 before storage (Figure 9). After storage, color levels were 32, 32, 32, 31, 32 and 31, for bales 1, 2, 3, 4, 5 and 6, respectively. Reflectance values were 73.5, 73.4, 73.1, 74.1, 74.0, and 74.3 for bales 1, 2, 3, 4, 5 and 6, respectively (Figure 10). Yellowness was 9.5, 9.4, 9.6, 9.1, 9.3, and 9.2 for bales 1, 2, 3, 4, 5 and 6, respectively. The final reflectance, Plusb, and color are also given in Figures 11-16 for each layer of each bale. The change in reflectance and Plusb is shown in Figure 17.

Bales with initial moisture levels of 12.7, 12.0 and 10.4% dropped from color 31 to color 32 during storage; however, the bale at 8.5% initial moisture did not drop in color as previous studies suggested. Unfortunately, the Rd and Plusb values for all the bales were near the line separating white from light spot as well as the line separating Middling from Strict Low Middling and created difficulties in interpreting the color data.

Conclusions

Care must be exercised in spraying water on cotton fiber at the lint slide to avoid fiber damage. The color of cotton degrades during storage at universal density when water is added to bring moisture levels above 8.5%.

Disclaimer

Mention of a trade name, propriety product or specific equipment does not constitute a guarantee or warranty by the United States Department of Agriculture and does not imply approval of a product to the exclusion of others that may be suitable.

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Table 1. Moisture before and after storage.

Bale number	Lint moisture, %			Water added, lb	Bale number, lbs	
	Lint flue	Tramper	After Storage		Initial	Final
1	4.9	12.7	8.2	40.4	518	497
2	4.7	10.4	7.0	28.2	494	484
3	4.7	12.0	7.6	37.7	517	494
4	4.7	8.5	6.4	18.8	495	490
5	4.9	4.8	6.1	0.0	453	460
6	4.8	7.4	6.6	12.4	479	478

Table 2. Summary of AFIS data **before** storage (see Appendix A for acronyms).

Bale number	Initial moisture, %	L(w)	UQL (w)	SFC (w)	L(n)	SFC (n)	L 2.5%	Fineness	IFC	Mat Ratio	Nep/ gm	SCN/ gm	Total dust	Dust/ gm	Trash/ gm	VFM
1	12.7	0.93	1.13	9.39	0.75	27.22	1.35	181.11	3.76	0.87	235.2	9.3	401.6	339.4	62.0	1.22
2	10.4	0.93	1.12	9.28	0.75	26.82	1.34	179.89	3.88	0.87	262.1	13.0	424.8	364.0	61.1	1.24
3	12.0	0.92	1.11	9.97	0.73	28.34	1.33	179.89	4.00	0.86	272.2	11.4	427.9	358.3	69.8	1.35
4	8.5	0.93	1.12	9.33	0.74	27.03	1.34	179.78	4.08	0.86	261.9	11.3	458.2	385.8	72.6	1.33
5	4.8	0.93	1.12	9.33	0.75	27.01	1.34	180.78	3.81	0.86	261.9	10.2	513.4	440.8	73.1	1.41
6	7.4	0.93	1.12	9.30	0.75	26.93	1.34	181.56	3.77	0.87	268.0	9.9	417.6	355.0	62.4	1.17

Table 3. Summary of AFIS data **after** storage.

Bale number	Initial Moisture %	L(w)	UQL (w)	SFC (w)	L(n)	SFC (n)	L 5%	L 2.5%	Fineness	IFC	Mat Ratio	Nep/ gm	SCN/ gm	Total dust	Dust/ gm	Trash/ gm	VFM
1	12.7	0.92	1.12	10.42	0.73	29.45	1.26	1.34	179.02	4.16	0.85	268.50	12.70	410.00	348.90	61.10	1.23
2	10.4	0.91	1.11	10.96	0.72	30.60	1.25	1.33	176.88	4.45	0.85	273.00	12.20	452.40	387.60	64.90	1.28
3	12.0	0.90	1.10	10.89	0.71	30.27	1.24	1.32	177.06	4.34	0.85	278.80	12.10	446.70	381.60	65.10	1.31
4	8.5	0.91	1.11	11.12	0.71	31.14	1.25	1.33	176.82	4.45	0.85	272.40	13.10	504.90	431.80	73.00	1.47
5	4.8	0.91	1.12	10.63	0.72	30.25	1.26	1.34	177.18	4.37	0.85	271.60	13.00	525.30	447.50	77.80	1.54
6	7.4	0.91	1.12	10.70	0.72	30.31	1.26	1.34	177.76	4.34	0.85	267.90	12.40	440.60	374.40	66.00	1.30

Table 4. High Volume Instrument classification **before** bale storage from samples at the lint slide immediately after moisture application. Samples were stored in paper bags prior to classification and were conditioned by AMS in accordance with standard practices.

Bale number	Initial moisture, %	Rd	Plus b	HVI color	Mike	Strength	Leaf	% Area	Length	Uniformity
1	12.7	74.71	9.17	31	4.70	27.01	2.7	0.24	1.07	81.4
2	10.4	74.25	9.05	31	4.58	27.55	2.9	0.29	1.07	81.8
3	12.0	74.56	8.86	31	4.61	26.80	2.7	0.24	1.07	81.7
4	8.5	74.33	9.02	31	4.67	26.93	2.9	0.28	1.06	81.6
5	4.8	73.29	9.23	32	4.59	27.00	3.0	0.31	1.07	81.7
6	7.4	73.63	9.14	31	4.65	26.93	2.8	0.31	1.06	81.6

Table 5. Summary of HVI data **after** storage.

Bale number	Initial moisture, %	Rd	Plus b	HVI Color	Mike	Strength	Leaf	% Area	Length	Uniformity
1	12.7	73.53	9.51	32	4.80	25.90	2.4	0.32	1.06	81.6
2	10.4	73.41	9.39	32	4.70	25.76	2.3	0.31	1.06	81.7
3	12.0	73.06	9.61	32	4.74	25.78	2.5	0.34	1.06	81.5
4	8.5	74.08	9.14	31	4.75	26.07	2.6	0.34	1.06	81.6
5	4.8	73.95	9.27	32	4.69	25.89	2.6	0.34	1.05	81.4
6	7.4	74.28	9.17	31	4.72	26.18	2.4	0.33	1.06	81.5

Figure 1. Bales stored near bale press.

Figure 2. The bales were opened at 10 different locations about 3” apart as shown by the nails.

Figure 3. Samples were taken at each layer.

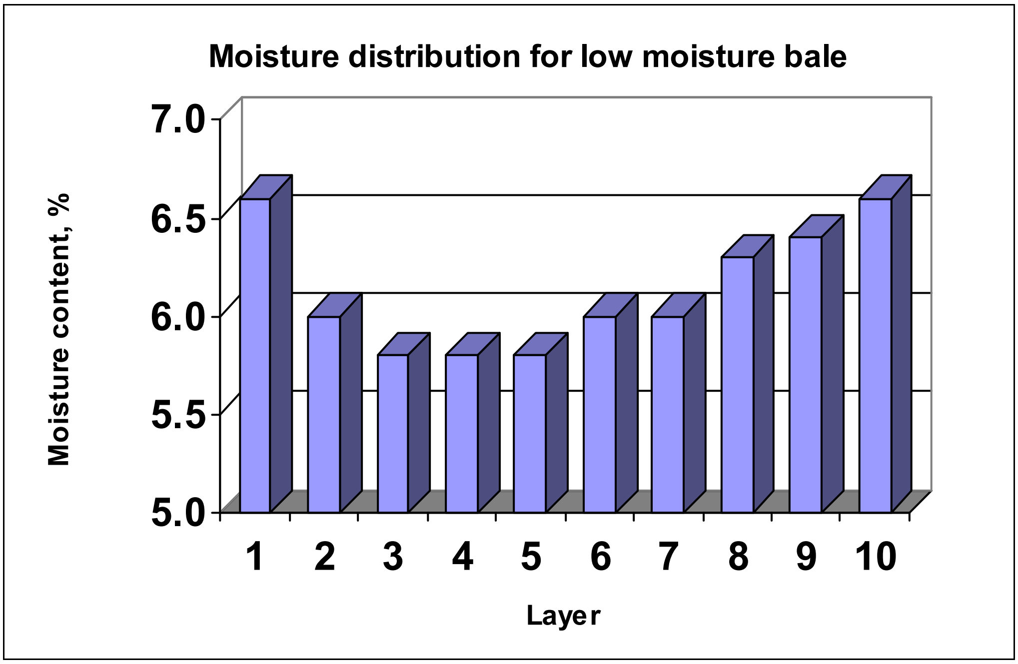

Figure 4. Average moisture at each of the 10 locations within the bale beginning about 3-inches from the exterior. Initial bale moisture was 4.8% and final moisture after storage was 6.1%. Bales were stored in strip-coated, woven polypropylene bags.

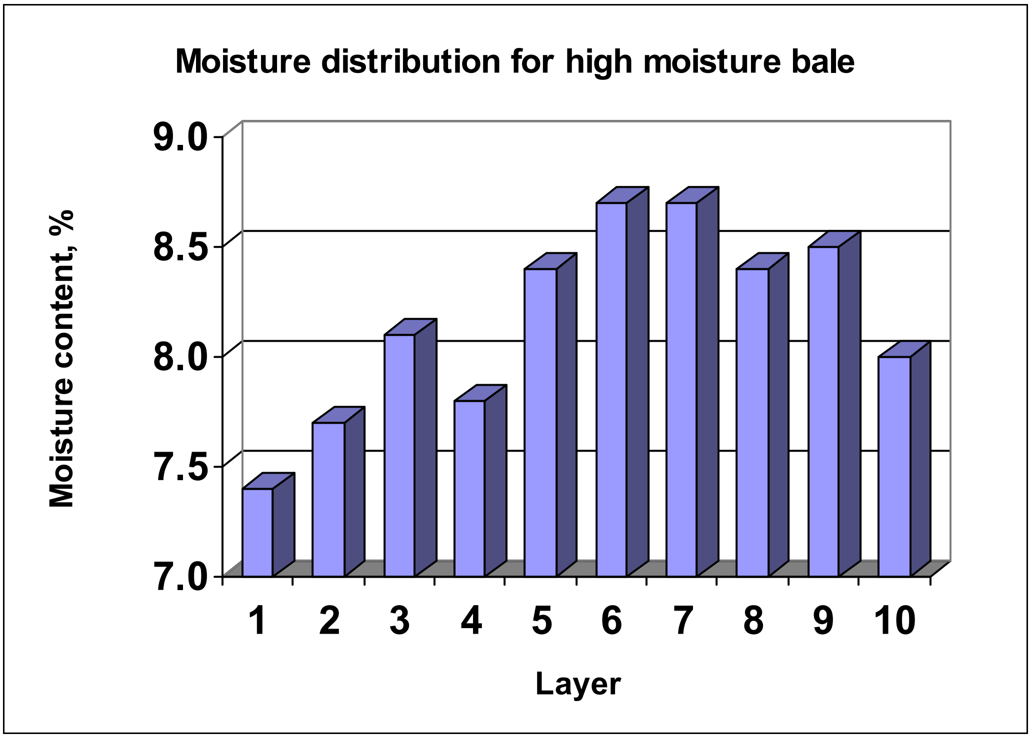

Figure 5. Average moisture at each of the 10 locations within the bale beginning about 3-inches from the exterior. Initial moisture was 12.7% and final bale moisture after storage was 8.2%. Bales were stored in strip-coated, woven polypropylene bags.

Figure 6. Discoloration occurred at the bale tie for the bales where moisture was added.

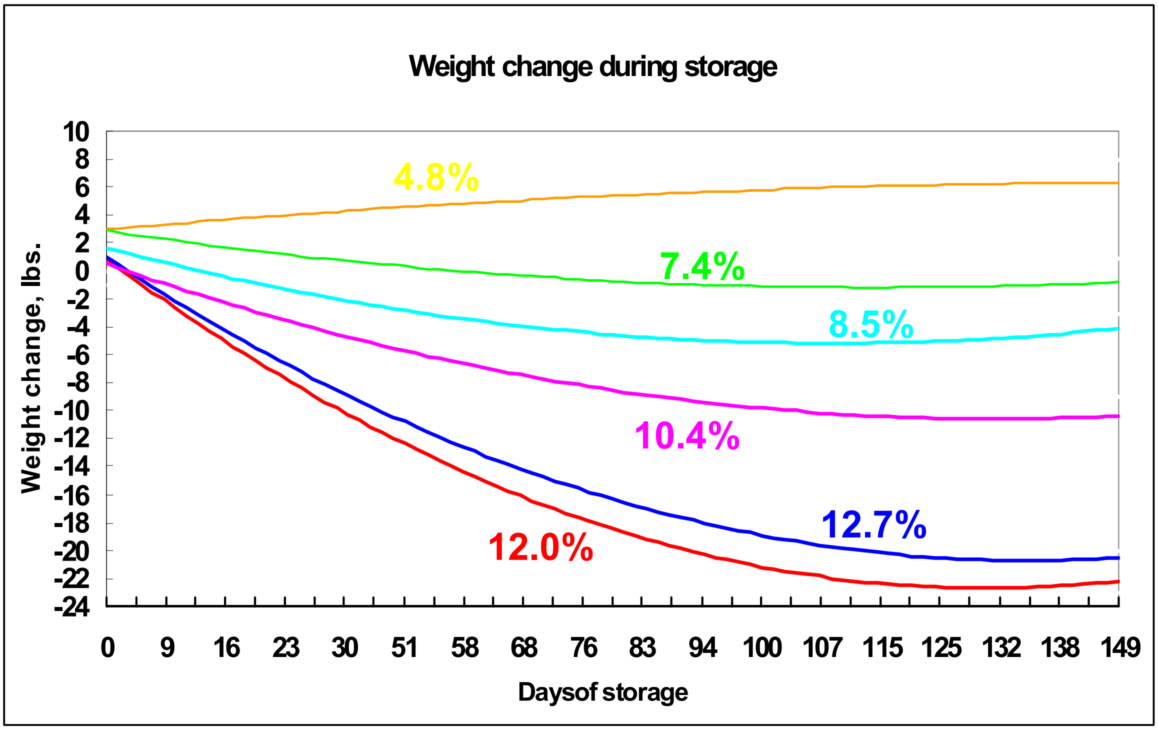

Figure 7. Weight change, lbs per bale, during storage. Note that all bales did not weigh the same initially. Moistures shown are initial, not final.

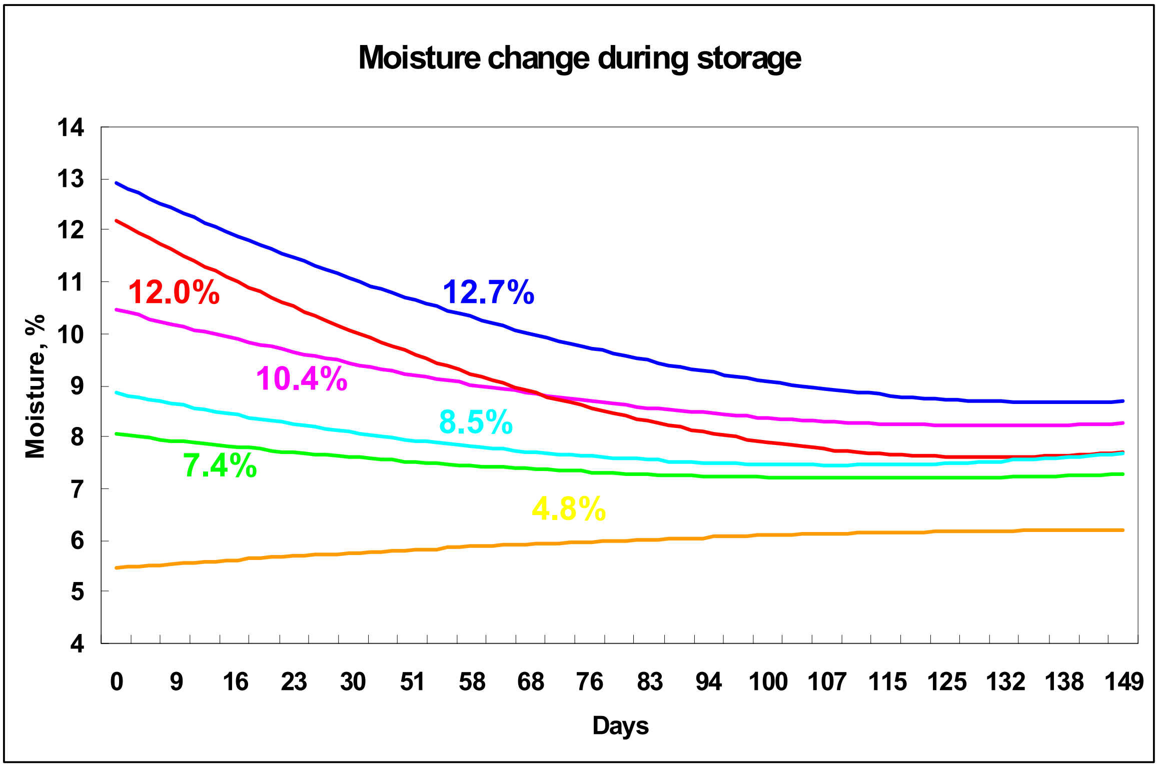

Figure. 8. Change in bale moisture content during storage in woven polypropylene, strip-coated bags. Moistures were calculated based on weight change of each bale.

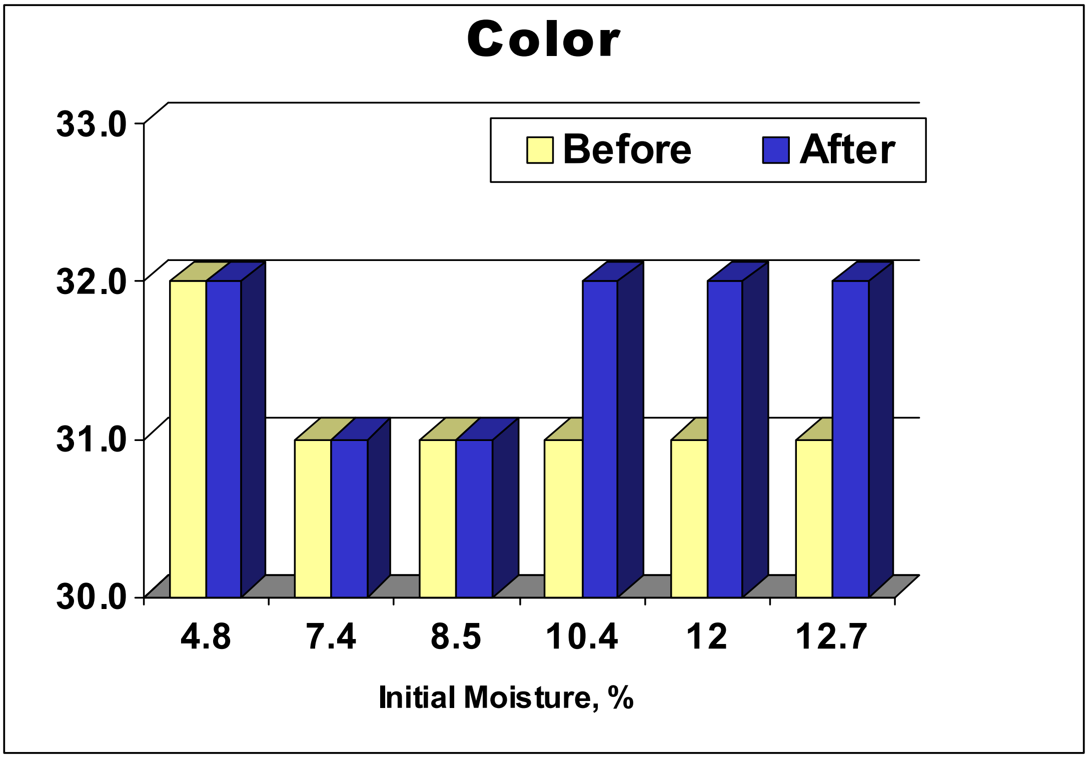

Figure 9. Impact of moisture on cotton color before and after bale storage (based on average Rd and +b).

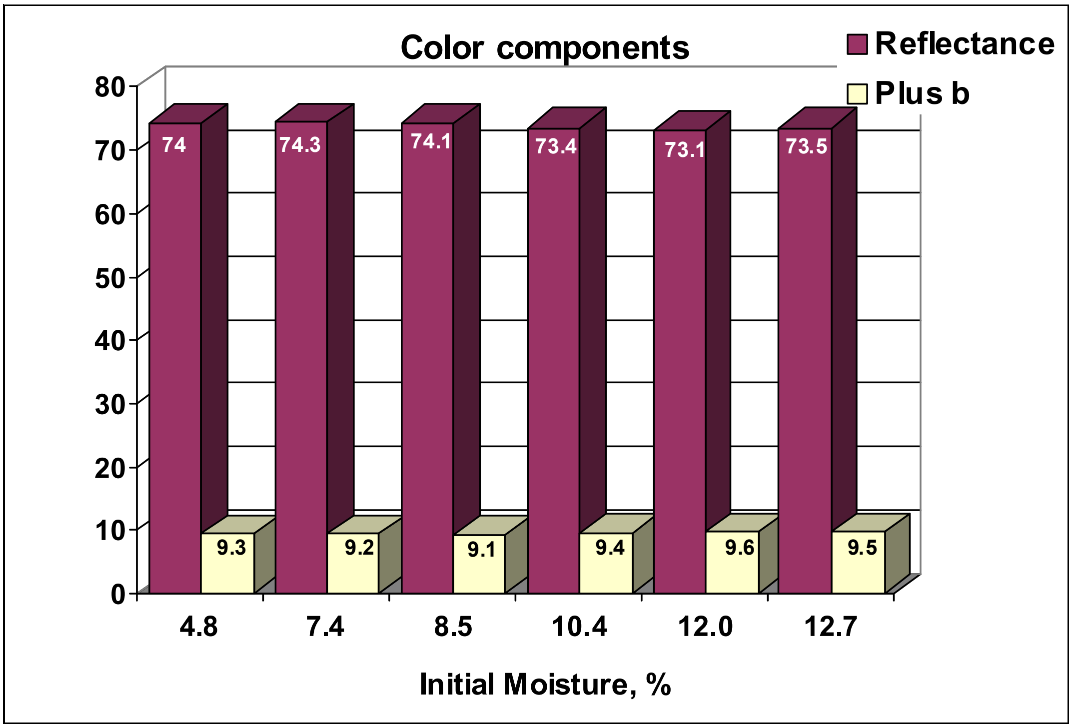

Figure 10. Cotton color factors before bale storage for 149 days at moisture levels of 4.8 to 12.7%. Bales were stored in strip-coated, woven polypropylene.

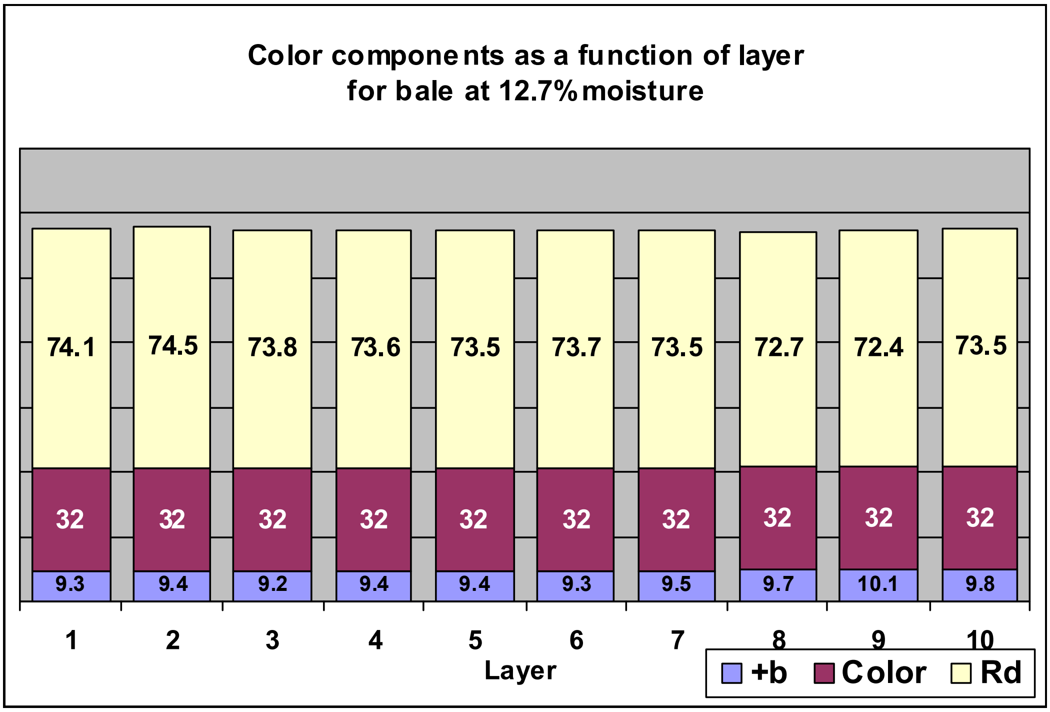

Figure 11. Color factors at different layers of a cotton bale at 12.7% moisture and decreasing to 8.2% after 149 days of storage in strip-coated, woven polypropylene bags.

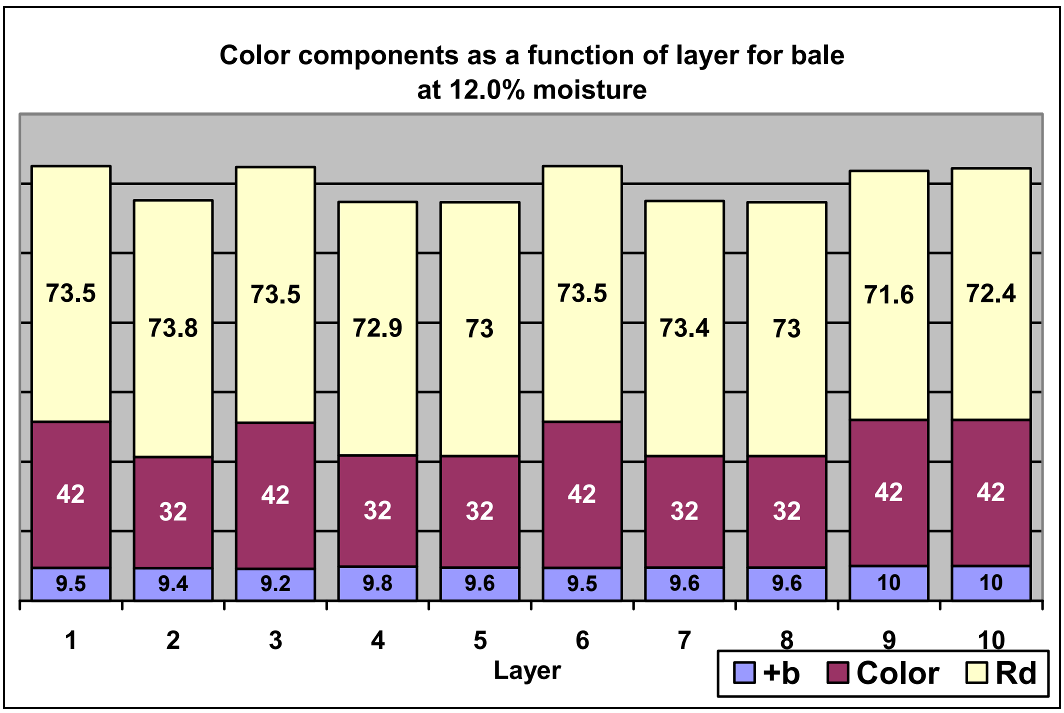

Figure 12. Color factor at different layers of a cotton bale at 12.0% moisture and declining to 7.6%. Bales were stored in strip-coated, woven polypropylene bags.

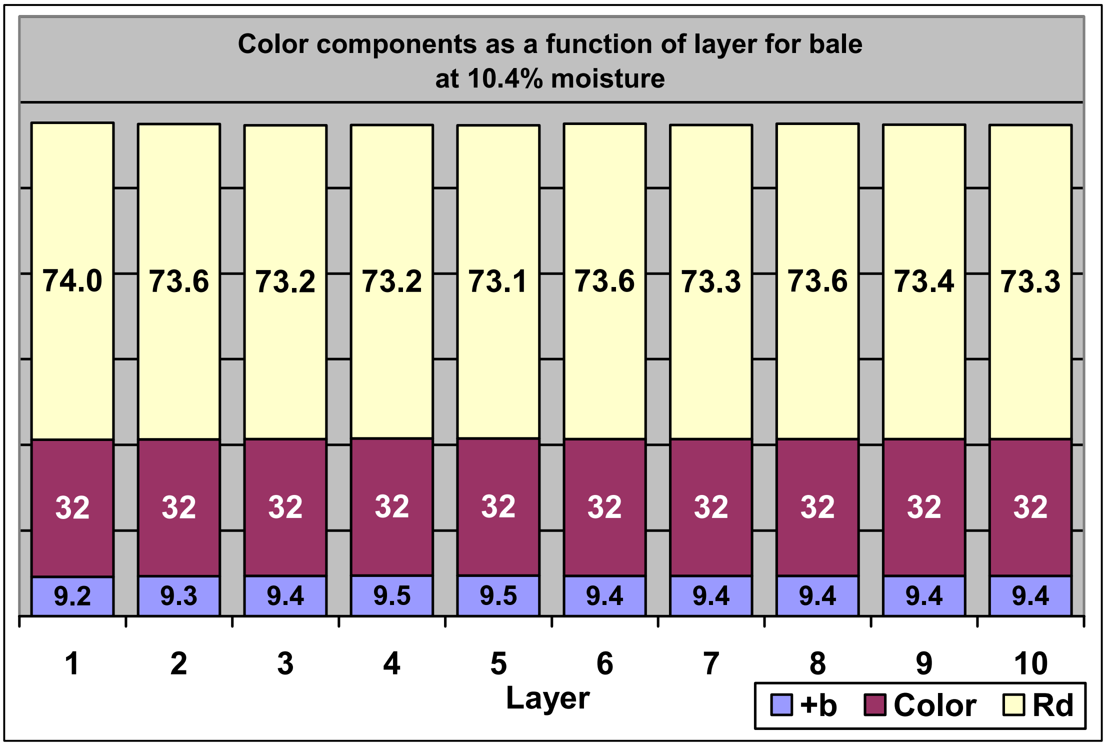

Figure 13. Color factors at different layers of a cotton bale at 10.4% moisture and declining to 7.0%. Bales were stored in strip-coated, woven polypropylene bags.

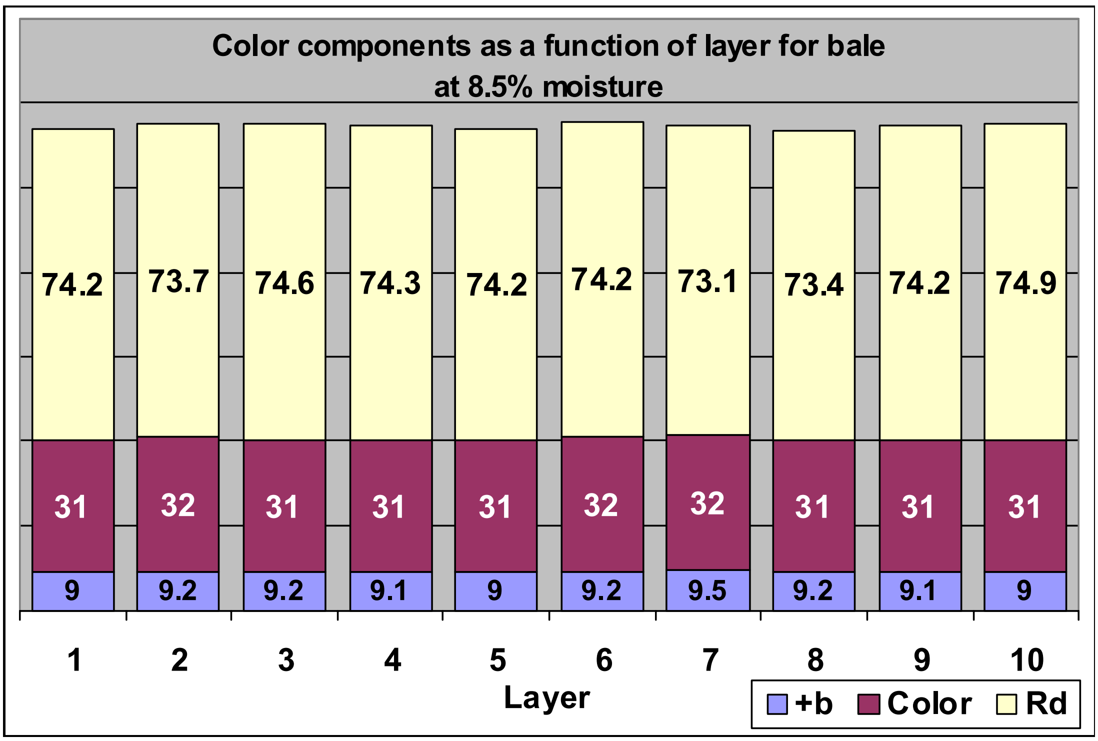

Figure 14. Color factors different layers of a cotton bale at 8.5% moisture and declining to 6.4%. Bales were stored in strip-coated, woven polypropylene bags.

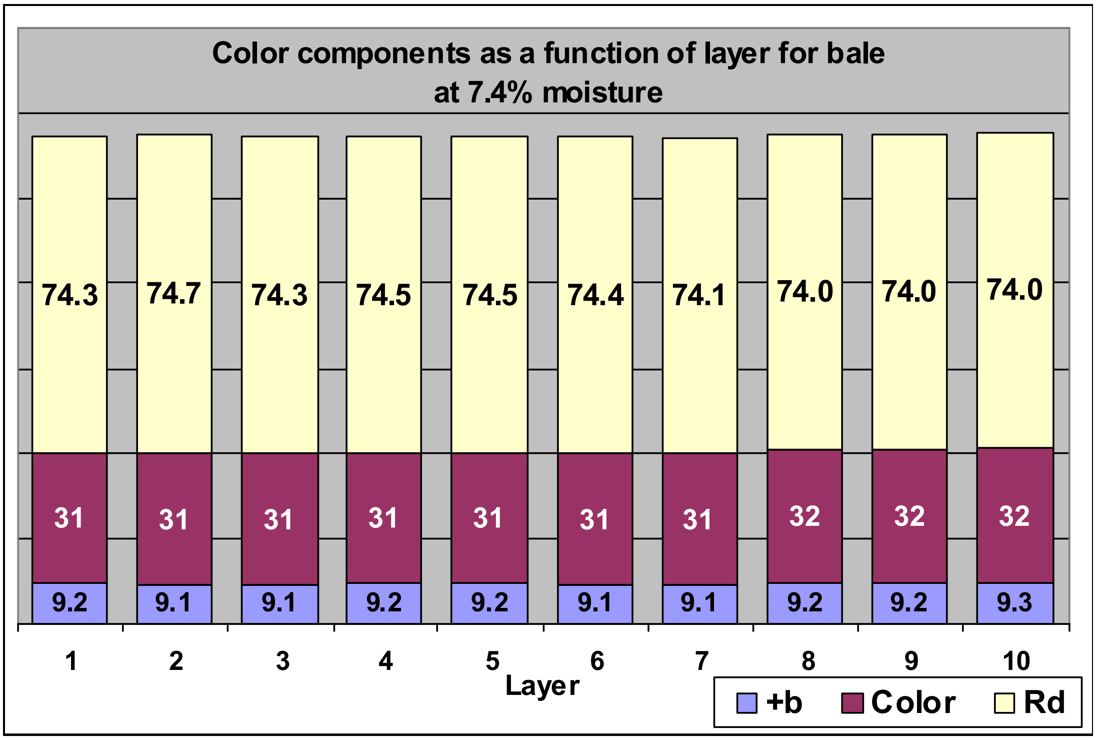

Figure 15. Color factors at different layers of a cotton bale at 7.4% moisture and declining to 6.6%. Bales were stored in strip-coated, woven polypropylene bags.

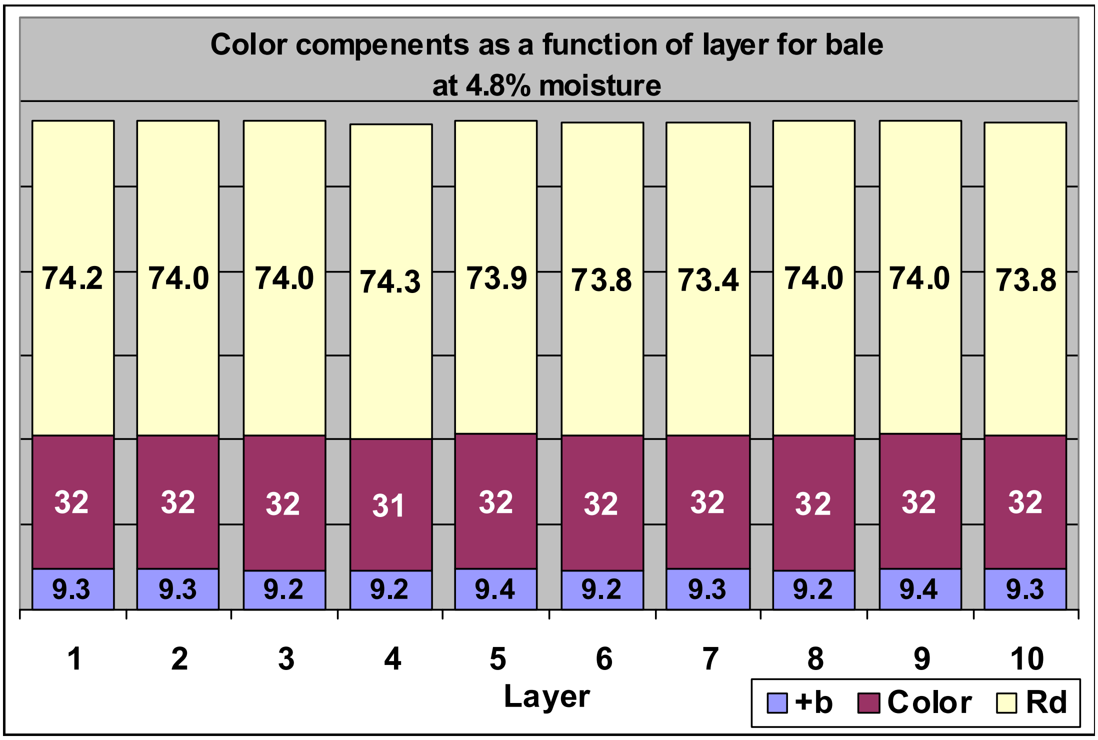

Figure 16. Color factors at different layers of a cotton bale at 4.8% moisture and increasing to 6.1%. Bales were stored in strip-coated, woven polypropylene bags.

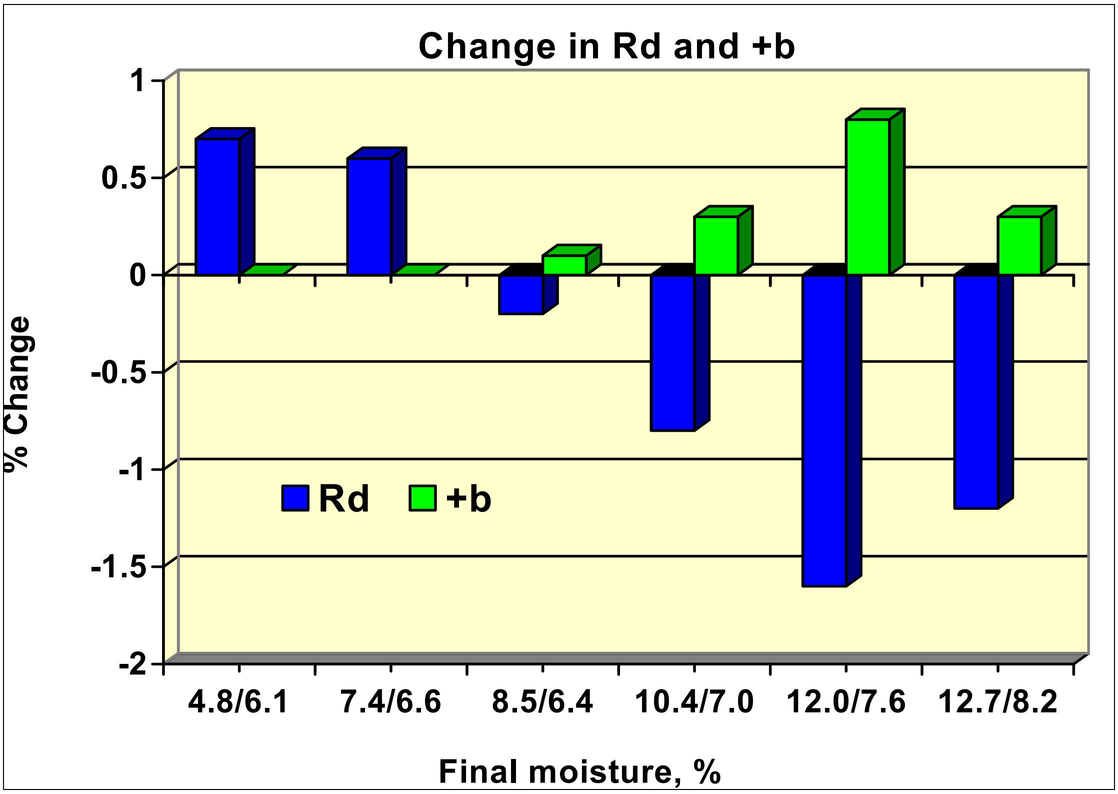

Figure 17. Change in reflectance (Rd) and yellowness (+b) during storage.

Nomenclature

Nep size [µm]	The mean size of all neps (both fiber and seed coat neps) in the sample.
Neps per gram	The total nep count normalized per gram. This includes both fiber and seed coat neps.
L(w) [in]	The average length of all the fibers in the sample computed on a weight basis.
L(w) CV [%]	The percentage of the coefficient of variation of the length by weight.
UQL(w) [in]	Upper Quartile Length by weight. This is the length which is exceeded by 25% of the fibers by weight.
SFC(w) [%]	The short fiber content of the sample (calculated by weight).
L(n) [in]	The average length of all the fibers in the sample computed on a number basis.
L(n) CV [%]	The percentage of the coefficient of variation of the length by number.
SFC(n) [%]	The short fiber content of the sample (actual fibers counted by number).
L5%(n) [in]	Percent 1 - The length, calculated by number, that is exceeded by five percent of the fibers.
L2.5%(n) [in]	Percent 2 - The length, calculated by number, that is exceeded by 2.5 percent of the fibers.
Total trash [count/gram]	Total trash consists of Trash and Dust; this is the total of the trash and dust count per gram of the sample.
Trash Size [µm]	The mean size of all the trash in the sample.
Dust [count/gram]	The particles measured by the Trash Module that are below the size defined as Dust on the Trash Report Type setup screen.
Trash [count/gram]	All foreign matter in cotton that is above the size defined as Dust is considered trash. This is the amount of trash per gram of the sample.
VFM [%]	The percentage of Visible Foreign Matter (dust and trash) in the sample.
SCN size [µm]	The mean size of all seed coat neps in the sample.
SCN per gram	The seed coat nep count normalized per gram.
Fine [mTex]	Fineness - Mean fiber fineness (weight per unit length) in millitex. One thousand meters of fibers with a mass of 1 milligram equals 1 millitex.

IFC [%]	Immature Fiber Content is the percentage of fibers with less than 0.25 maturity. The lower the IFC%, the more suitable the fiber is for dyeing.
Mat Ratio	Maturity Ratio - The ratio of fibers with a 0.5 (or more) circularity ratio divided by the amount of fibers with a 0.25 (or less) circularity. The higher the maturity ratio, the more mature the fibers are and the better the fibers are for dyeing.
Micronaire	Micronaire is a measure of fiber fineness and maturity.
Strength	Strength measurements are reported in terms of grams per tex. A tex unit is equal to the weight in grams of 1,000 meters of fiber.
Rd and Plusb	The color of cotton is determined by the degree of reflectance (Rd) and yellowness (+b). Reflectance indicates how bright or dull a sample is, and yellowness indicates the degree of color pigmentation.
Area	Trash is a measure of the amount of non-lint materials in the cotton, such as leaf and bark from the cotton plant. The surface of the cotton sample is scanned by a video camera and the percentage of the surface area occupied by trash particles is calculated.
Length	Fiber length is the average length of the longer one-half of the fibers (upper half mean length). It is reported in 32nds of an inch.
Uniformity	Length uniformity is the ratio between the mean length and the upper half mean length of the fibers and is expressed as a percentage.